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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**ENABLING THE COMMERCIAL SPACE TRANSPORTATION
INDUSTRY AT THE MID-ATLANTIC REGIONAL SPACEPORT**

by

Nathan J. Winters

September 2011

Thesis Advisor:
Second Reader:

Daniel Bursch
Charles Racoosin

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**ENABLING THE COMMERCIAL SPACE TRANSPORTATION INDUSTRY AT
THE MID-ATLANTIC REGIONAL SPACEPORT**

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requirements for the degree of

MASTER OF SCIENCE IN SPACE SYSTEMS OPERATIONS

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ABSTRACT

The focus of this paper is on how to energize the space industrial base as directed by the National Security Space Strategy of 2011. Using a case study of the Mid-Atlantic Regional Spaceport (MARS), an analysis of how to enable the commercial space transportation industry will be discussed. A look at previous government ventures that have been privatized, along with the history of commercial space transportation, sets the stage for evaluating the future of the industry. An in-depth analysis of FAA and NASA regulation was done to compare and contrast the advantages and disadvantages of each and provide insight on the future regulation of the industry. Past launches, government funding, and future plans are all studied to determine a forecast for demand. Recommendations are provided to the MARS on how to enable their commercial space transportation industry and conclusions are drawn on the importance of the commercial space transportation industry to National Security.

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LIST OF ACRONYMS AND ABBREVIATIONS

AST	FAA Office of Commercial Space Transportation
C3PO	Commercial Crew and Cargo Program Office
CCDev	Commercial Crew Development Program
CCTS	Commercial Crew Transportation System
CEV	Crew Exploration Vehicle
COMSTAC	Commercial Space Transportation Advisory Committee
COTS	Commercial Orbital Transportation Services
CSLAA	Commercial Space Launch Amendments Act
CST&EI	Commercial Space Transportation and Enabled Industries
CDR	Critical Design Review
CRS	Commercial Resupply Service
CRuSR	Commercial Reusable Suborbital Research
DoD	Department of Defense
EELV	Evolved Expandable Launch Vehicle
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FBO	Fixed Base Operator
GAO	General Accounting Office
GLOW	Gross Lift-Off Weight
GOCO	Government Owned Contractor Operated
GPS	Global Positioning System
ISS	International Space Station

ITAR	International Traffic in Arms Regulation
LADEE	Lunar Atmosphere & Dust Environment Explorer
LEO	Low Earth Orbit
LOC	Loss of Crew
LVM&SI	Launch Vehicle Manufacturing and Services Industry
MARS	Mid-Atlantic Regional Spaceport
MIST	Mid-Atlantic Institute of Space and Technology
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NSS	National Security Space
NTSB	National Transportation Safety Board
OCST	Office of Commercial Space Transportation
ORR	Operational Readiness Review
ORS	Operationally Responsive Space
OSC	Orbital Science Corporation
PDR	Preliminary Design Review
R&D	Research and Development
RSAA	Reimbursable Space Act Agreement
SAA	Space Act Agreement
SDR	System Definition Review
SRR	System Requirements Review
USML	United States Munitions List
VCSCFA	Virginia Commercial Space Flight Authority

VSE	Vision for Space Exploration
VTVL	Vertical Takeoff Vertical Landing
WFF	Wallops Flight Facility

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I. INTRODUCTION

A recurring theme in recent space policy is the emphasis on leveraging the commercial space industry. An example is one of the goals of the 2010 U.S. Space Policy:

Energize competitive domestic industries to participate in global markets and advance the development of: satellite manufacturing; satellite-based services; space launch; terrestrial applications; and increased entrepreneurship. (The White House, 2010)

The 2011 National Security Space Strategy uses similar terminology in one of its three strategic objectives: “Energize the space industrial base that supports U.S. national security” (The White House, 2011). This language can be found throughout current space policy and shows an increasing trend towards relying on the commercial space transportation industry.

This goal of shifting space goods and services from the government to private industry is reminiscent of many past government investments. Ventures by the government in research and development (R&D) and infrastructure creation are prevalent throughout our recent history; such as railroads, telecommunications infrastructure, interstate highways, and more recently the airline industry. These examples demonstrate how this initial investment, which is often prohibitively expensive for the commercial industry, can be a viable investment for the government. This government investment attracts private industry into the emerging market and ultimately turns into a new and profitable commercial industry. It is in the U.S. Government’s strategic interest to provide financial and technical assistance in developing new commercial space transportation capabilities (NASA, 2011).

Current space policy is attempting to give private industries the opportunity to capitalize on the space business while simultaneously easing the burden of an overextended and underfunded government space program. While the National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD)

have held the leading role in providing space services, this is beginning to change. The commercial expansion into space has prompted the Federal Aviation Administration (FAA) to begin regulating these activities while NASA continues to follow their own regulations and standards. With NASA's retirement of the space shuttle program in 2011, they will become dependent on the commercial space transportation industry. How the FAA, NASA, or some combination of the two will regulate this new industry, is in question. Sensible regulation will be required to ensure the success of this emerging market. This transition will change how the government, DoD, and commercial industry will access space.

II. BACKGROUND

A. HISTORY

The first privately funded commercial space flight to break the 100 kilometer mark was SpaceShipOne built by Scaled Composites in 2004. After a second flight, they were awarded the Ansari X-prize for suborbital space flight. This achievement was heavily publicized and received attention from numerous companies and investors which invigorated the commercial space industry. Even though the commercial space industry had been in existence for some time, the X-prize brought worldwide recognition and renewed publicity into this emerging industry.

The first U.S. regulation of the commercial space industry began with the passage of the Commercial Space Launch Act (CSLA) in 1984. This act was amended in 2004 and is the most current policy affecting the commercial space transportation industry. The CSLA gives the FAA authority to regulate the commercial space industry and prevents the government from being held liable for the high risks associated with suborbital flight. This policy allows the use of experimental permits to encourage research and development projects without excessive liabilities that would curtail investment. The Office of Commercial Space Transportation (AST) was created within the FAA and is responsible for regulating and promoting the commercial space transportation industry.

NASA has also developed its own policy and procedures for space flight, but has always maintained oversight and control of its own space services. It is only recently that NASA has changed policy to focus on space travel beyond Low Earth Orbit (LEO). With the retirement of the space shuttle program all future access to LEO from the U.S. will be purchased from the newly emerging commercial space transportation industry. The first phases of this plan include funding resupply missions to the International Space Station (ISS) and a Commercial Crew Development Program (CCDev) to provide crew transportation to and from the ISS (NASA IG, 2011).

B. SPACEPORTS

The growth of the commercial space transportation industry is apparent based on the number of new spaceports already licensed or in the process of being licensed by the FAA. Figure 1 displays a map of FAA licensed U.S. spaceports. These spaceports vary in their operational status ranging from new construction to existing federal ranges and closed military airfields. Several proposed spaceports are in the licensing process while others such as the Gulf Coast Regional Spaceport have terminated their plans. Out of all the spaceports, only four U.S. based spaceports are licensed to launch payloads to orbit: the Mid-Atlantic Regional Spaceport (MARS), Kennedy Space Center, Vandenberg Air Force Base, and the Kodiak Launch Complex.

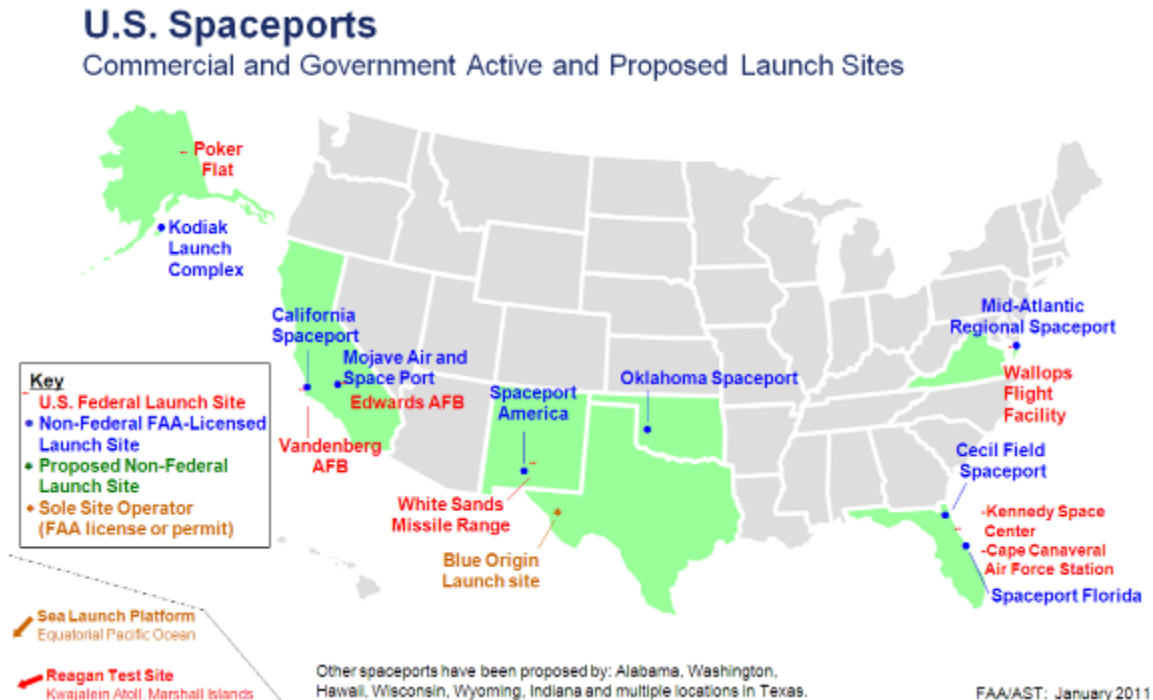


Figure 1. FAA AST Licensed Spaceports

C. LAUNCHES

The graph in Figure 2 shows the increase in commercial launch revenues from 2008 through 2010. This trend has been positive even through a global recession. This

growth is attributed to increased globalization, technology improvements, deregulation, access to previously closed countries, and continued growth in developing countries (FAA AST, 2011). Launch demand is expected to continue with the growth of the commercial space industry. The availability of new markets such as ISS resupply and CCDev will increase U.S. launch demand. These launches do not include the nascent sub-orbital market that is expected to commence commercial flights in 2013. The U.S. has ranked third or fourth in commercial launches over the past four years. A large portion of the launch market has been lost to foreign competitors.

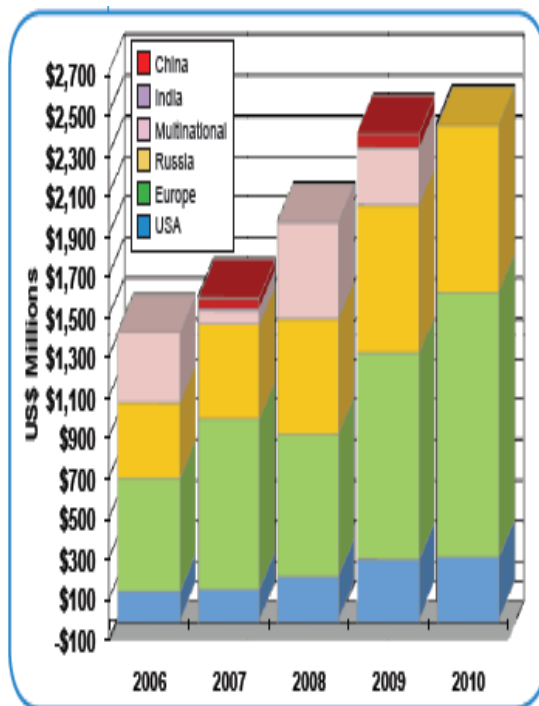


Figure 16. Approximate Launch Revenues for Commercial Launch Events (2006-2010)

	2006	2007	2008	2009	2010
United States	\$140	\$150	\$215	\$298	\$307
Russia	\$374	\$477	\$581	\$742	\$826
Europe	\$560	\$840	\$700	\$1,020	\$1,320
China	\$0	\$50	\$0	\$70	\$0
India	\$0	\$11	\$0	\$0	\$0
Multinational	\$350	\$70	\$475	\$280	\$0
TOTAL	\$1,424	\$1,598	\$1,971	\$2,410	\$2,453

Table 9. Estimated Commercial Launch Revenues, 2006–2010 (US\$Millions)

Figure 2. FAA AST Commercial Launch Revenues, 2006–2010

The U.S. commercial space industry has been hindered by having satellites, launch vehicles, and other related components placed on the U.S. Munitions List (USML). Any items on the USML require an export license from the U.S. State Department and are controlled by the International Traffic in Arms Regulation (ITAR).

These additional restrictions have prevented some companies from working with international customers and have caused delays and cancellations of satellite programs (FAA AST, 2011). Thales Alenia Space and Astrium Satellites advertise their products as “ITAR-free.” This is possible because they do not use any U.S. parts that fall under the USML. This allows them to sell their products to a larger foreign market with less regulation. Export reform to remove satellites and related components from the USML has been attempted. The latest version, House of Representatives bill 1727, has been in committee since May 2011.

The uncertainty of future launch demand has made it difficult to plan operations and pursue savings through economies of scale. The DoD has tried to reduce this uncertainty by announcing plans to purchase eight launches per year starting in 2013. This was implemented to provide a stable government launch market in the hopes of reducing costs. The commercial space transportation industry has no such guarantees and must first prove their rockets reliability before they will be considered for government launches. Even with this unproven reliability, as of September 2011, SpaceX has signed contracts for 38 Falcon 9 launches.

The economic performance data for Commercial space transportation and enabled industries (CST&EI) is shown in CST&EI economic impact totals (in then year dollars). Table 1 shows a steady increase in the economic impact from the commercial space transportation industry. The economic performance data for launch vehicle manufacturing and services industry (LVM&SI) is shown in Table 2 with the previously mentioned decline in launches. While the industry has been growing steadily over the past 10 years there has been a decrease in LVM&SI due to foreign competition.

	2002	2004	2006	2009
Economic Activity (\$000)	\$95,025,746	\$98,086,960	\$139,262,027	\$208,329,012
Direct (\$000)	\$16,959,859	\$16,666,148	\$23,240,911	\$34,845,418
Indirect (\$000)	\$46,715,917	\$46,382,890	\$65,031,780	\$97,331,013
Induced (\$000)	\$31,349,971	\$35,037,924	\$50,989,338	\$76,152,583
Earnings (\$000)	\$23,527,745	\$25,045,888	\$35,659,935	\$53,257,346
Employment	576,448	551,350	729,240	1,029,440

Table 1. CST&EI economic impact totals (in then year dollars)

	2002	2004	2006	2009
Economic Activity (\$000)	\$791,759	\$1,658,384	\$1,166,723	\$827,817
Direct (\$000)	\$149,273	\$286,936	\$199,195	\$141,334
Indirect (\$000)	\$367,530	\$759,171	\$527,028	\$373,939
Induced (\$000)	\$274,956	\$612,277	\$440,500	\$312,545
Earnings (\$000)	\$206,328	\$437,674	\$308,087	\$218,595
Employment	4,828	8,870	5,690	3,820

Table 2. LVM&SI economic impact totals (in then year dollars)

D. POLICY

The FAA, under the Department of Transportation, created the Office of Commercial Space Transportation (AST) to regulate the commercial space market in response to the emerging commercial space industry and articles VI and VII of the 1967 United Nations Outer Space Treaty. In this treaty the location and nation of origin of the

launch operator can be held responsible for any damages or accidents that occur. To mitigate this risk the FAA AST was created. Their mission is:

To ensure the protection of the public, property, and the national security and foreign policy interests of the United States during commercial launch or reentry activities, and to encourage, facilitate, and promote U.S. commercial space transportation. (FAA, 2010)

This mission and its associated regulations do not currently include NASA launches, though they are expected to require FAA licensing in the future (FAA, 2011).

NASA's current requirements and regulations could negatively impact commercial space. These requirements are the reason NASA is partially funding development of crew services in the commercial space industry. NASA understands additional requirements lead to additional costs and is willing to offset those costs. However, even with NASA funding, this emerging market is prone to failures. For example, California-based Rocketplane Kistler Inc. declared bankruptcy in 2010 despite NASA funding. While failures in any industry are to be expected, they are especially painful in the space sector due to its complexity and high cost. This is compounded by the fact that the commercial space transportation market has not yet stabilized with a reliable customer base. The jobs, technology, and investment lost due to business failure have a negative impact on the entire market. In the case of Rocketplane, the company had received 32 million dollars in milestone payments from NASA that could have been invested in another commercial space company. The remaining 175 million dollars in Rocketplane's contract were recompeted and awarded to Orbital (FAA AST, 2011).

III. FAA

The FAA has been issuing licenses to the commercial space transportation industry since 1995. The Office of Commercial Space Transportation (AST) issues licenses for commercial launches of orbital and suborbital rockets. AST's focus on promoting and encouraging commercial space transportation is paramount to enabling this industry.

A. ORGANIZATION

The FAA AST has three divisions: Space Systems Development, Licensing and Safety, and Systems Engineering and Training. The Space Systems Development Division provides space systems engineering, space policy, and economic and launch forecast capabilities. The Licensing and Safety division ensures public health and safety by licensing commercial space launches and re-entries. The Systems Engineering and Training division defines safety standards for existing and emerging space launch and re-entry systems and sites while defining methods to assure and verify that those standards are met (FAA, 2011).

B. SCOPE

FAA AST regulations apply to all non-government sub-orbital and orbital space transportation within the United States. The purposes of these regulations are to protect the safety of the general public and the crew. Ensuring proper safety without curtailing investment is one of the major challenges these regulations pose to potential commercial ventures. To encourage investment the FAA's AST has created a Commercial Space Transportation Grant Program. This program has 500,000 dollars available in matching grants to be used for space transportation infrastructure projects. These grants were awarded to Kodiak Launch Complex, Alaska; Mojave Air & Spaceport, California; Spaceport America, New Mexico; and Cecil Field, Florida.

C. REGULATION

FAA regulation has evolved from the Commercial Space Launch Agreement Act of 2004 to the Final Rule on Human Space Flight Requirements for Crew and Space Flight Participants. This Final Rule included input from over forty companies and is similar to the requirements placed on the airline industry. The safety of the general public is the primary concern of this regulation. The safety of the crew and passengers, while still important, is based on informed consent with the understanding that space flight is dangerous and the FAA does not certify vehicles as being safe for space flight. This Final Rule requires insurance and training to ensure all crew members are aware that space flight is inherently dangerous (FAA, 2006).

The current policy prohibits the FAA from regulating crew and passenger safety before December 2012, except in the case of casualties or excessive damage. This is meant to allow increased research and development in the emerging commercial space transportation industry. Since there are no existing data for the majority of new space transportation systems being developed, the FAA plans to determine its future policy and standards from lessons learned and the sharing of best practices from the commercial space transportation companies (GAO, 2011).

The FAA issues four types of licenses: a launch license (for expendable launch vehicles), a reusable launch vehicle mission license, a reentry license, and a launch or reentry site operator license. The first three types of licenses are issued to the operator of a launch vehicle and the latter is issued to the operator of a spaceport. Figure 3, U.S. Commercial Launches, shows the number of FAA licensed and permitted launches from 1997 to 2010. In 2006, permits were authorized as an alternative to licenses for reusable suborbital rockets. Permits may be issued for research and development and to show compliance with license requirements and crew training. Permits allow unlimited launches; however, they cannot be used on flights for compensation or hire.

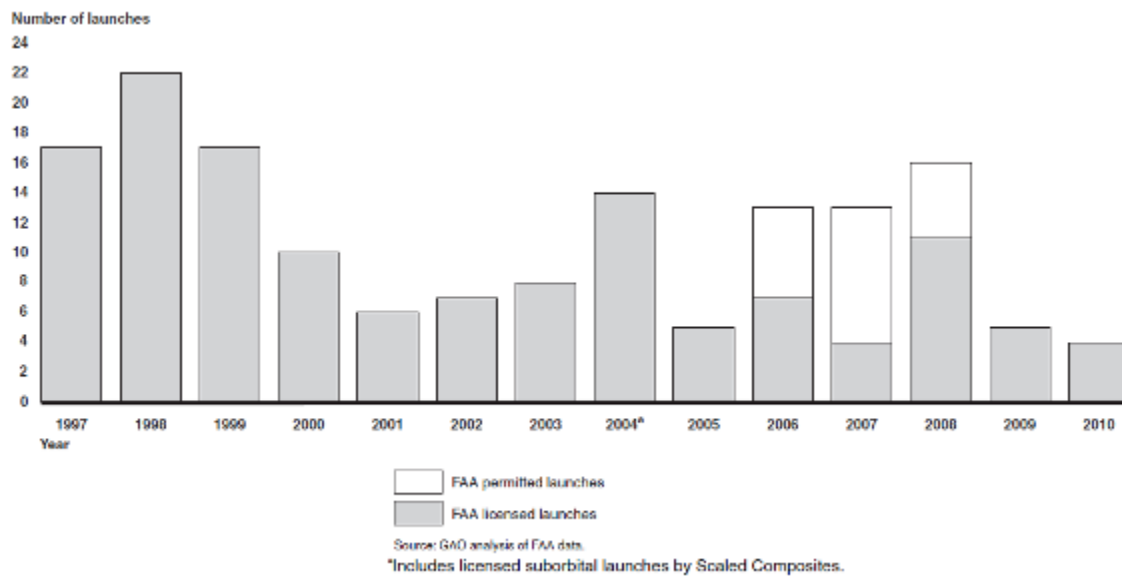
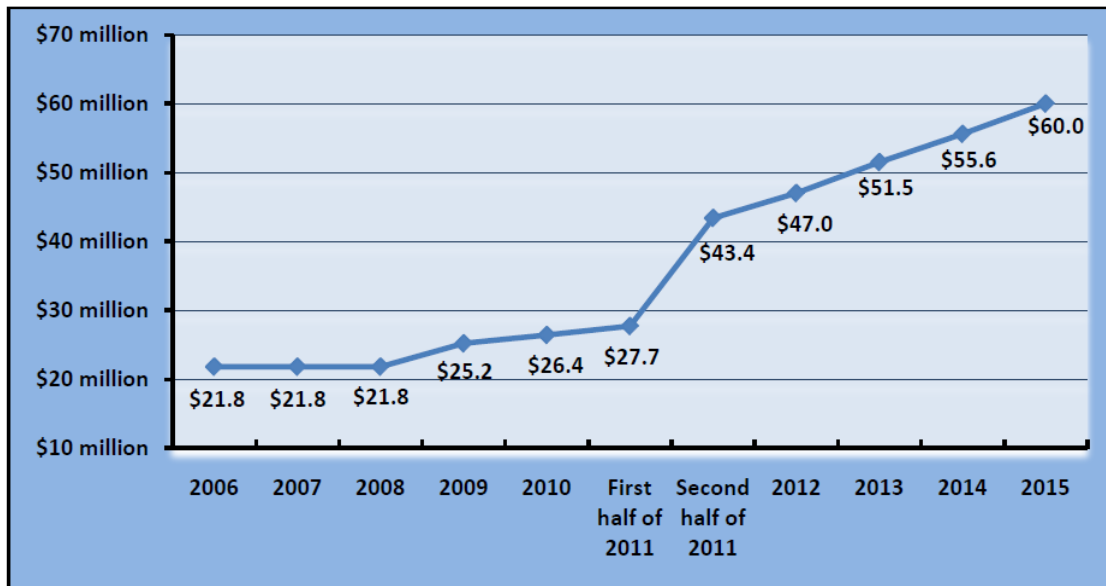


Figure 3. U.S. Commercial Launches (GAO, 2011)

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IV. NASA

NASA has created and maintained its own internal regulations for space transportation. With the retirement of the Space Shuttle, NASA will be reliant on commercial services for access to and from Low Earth Orbit (LEO). NASA missions are expected to fall under FAA licensing in the future. NASA has published Commercial Crew Transportation System Certification Requirements for NASA LEO Missions. This new regulation has been vetted by both the commercial industry and government agencies. Until the commercial space industry has proven itself to meet NASA's standards, NASA will purchase transportation to the International Space Station (ISS) from Russia at approximately 65 million dollars a seat. Through 2015 NASA has purchased 46 seats aboard Soyuz vehicles. Figure 4 depicts the cost of purchasing a single seat aboard the Soyuz vehicle for launches through 2015.



Source: NASA International Space Station External Integration Office, Johnson Space Center, May 2011.

Figure 4. Yearly Cost (per seat) for U.S. Transportation Services Aboard Soyuz

A. ORGANIZATION

NASA has started several initiatives to encourage commercial space transportation development. These include the Commercial Orbital Transportation Services (COTS) program, the Commercial Crew Development (CCDev) program, and the Commercial Resupply Services (CRS) contract. NASA funds these programs through private industry to support NASA operations. These programs are managed by NASA's Commercial Crew and Cargo Program Office (C3PO). The mission of C3PO is to “extend human presence in space by enabling an expanding and robust U.S. commercial space transportation industry” (NASA, 2010).

B. SCOPE

NASA’s new Commercial Crew Transportation policy applies only to NASA missions to LEO and would be in addition to any FAA requirements. NASA certification would involve validation of technical and performance standards, verification of compliance, consideration of relevant operational experience, and acceptance of residual technical risk. It also states that NASA will be required to “analyze the risk and decide on necessary steps for safety when putting NASA personnel in harm’s way using designs or operations that NASA does not control” (NASA, 2010).

Commercial Resupply Service (CRS) contracts were awarded to SpaceX and Orbital Sciences Corporation through 2016. SpaceX was awarded 1.6 billion dollars for twelve resupply missions to the International Space Station (ISS). Orbital Sciences Corporation was awarded 1.9 billion dollars for eight resupply missions. Both private companies have made significant progress towards their resupply goals with launches scheduled as early as November 2011. SpaceX has received permission from NASA to combine their November test flight and their first ISS docking flight into one mission. Orbital Sciences Corporation is planning their initial test flight from Wallops Flight Facility (WFF) Mid-Atlantic Regional Spaceport (MARS) in December 2011.

The first round of the Commercial Crew Development (CCDev) program was awarded to five private companies: Blue Origin, Boeing, Paragon Space Development

Corporation, Sierra Nevada Corporation, and the United Launch Alliance. The associated Space Act Agreements (SAA) ranged from one to twenty million dollars with a total of fifty million dollars from the American Recovery and Reinvestment Act. These competitive awards are pre-negotiated, milestone-based agreements to support commercial space transportation development with a fixed government investment.

The second round of CCDev included 269 million dollars awarded to the following four companies: Blue Origin, Sierra Nevada Corporation, Space Exploration Technologies, and the Boeing Company. The awards ranged from twenty-two million dollars to ninety-two million dollars. The associated SAA's have required milestones that must be met for these private companies to continue in the program. A third round of CCDev will be awarded in 2012. Table 3 lists all commercial crew and cargo awards.

Program	Year of Space Act Agreement	Value of Space Act Agreement	Companies	Vehicles and Technologies
COTS	2006	\$278 million	SpaceX	Dragon
COTS	2006	\$207 million	Kistler	K-1
COTS	2007	\$175 million	Orbital	Cygnus
CRS	2008	\$1.5 billion	SpaceX	Dragon (12 flights)
CRS	2008	\$1.9 billion	Orbital	Cygnus (8 flights)
CCDev 1	2010	\$20 million	Sierra Nevada Corp.	Dream Chaser
CCDev 1	2010	\$18 million	Boeing	CST-100
CCDev 1	2010	\$6.7 million	United Launch Alliance	Atlas/Delta crew certification
CCDev 1	2010	\$3.7 million	Blue Origin	Launch abort systems
CCDev 1	2010	\$1.4 million	Paragon Space	Life support
CCDev 2	2011	\$92.3 million	Boeing	CST-100 design maturation
CCDev 2	2011	\$80 million	Sierra Nevada Corp.	Dream Chaser design maturation
CCDev 2	2011	\$75 million	SpaceX	Crewed Dragon development
CCDev 2	2011	\$22 million	Blue Origin	Launch abort systems
FY 2012 NASA request*				
CCDev Follow-on	2012	\$850 million	TBD	TBD

* From http://www.nasa.gov/pdf/516674main_FY12Budget_Estimates_Overview.pdf

Table 3. NASA Commercial Crew and Cargo Awards

These programs are vital to provide startup space companies a reliable funding source to develop these high risk and highly technical space systems. Without this investment many of these companies would not be able to sustain themselves in the volatile space market. As previously mentioned, Rocketplane, one of the original CCDev awardees, has already declared bankruptcy. Sea Launch is another example of a commercial space company that has taken risks in this emerging market and has faced setbacks. Their unique launch platform was damaged during a failed launch in 2007. This failed launch along with a loss of the market due to delays and questions of reliability resulted in the company filing for bankruptcy protection in 2009. Even with this significant setback Sea Launch emerged from bankruptcy in 2010 and has a launch scheduled for September 2011.

C. REGULATION

NASA's Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions, while fewer than 40 pages, references over 70 other documents with additional requirements. These documents require a program manager and five separate milestone reviews for any commercial crew transportation systems. These reviews are: System Requirements Review (SRR), System Definition Review (SDR), Preliminary Design Review (PDR), Critical Design Review (CDR), and Operational Readiness Review (ORR). Additionally, any change that affects crew safety requires approval from the Johnson Space Center Director.

NASA's safety requirements for commercial crew transport are also required to be an order of magnitude safer than the Space Shuttle. Specifically, NASA requires a Loss of Crew (LOC) probability of no greater than 1 in 1000 launches for both ascent and entry. The LOC probability for a 210 day ISS mission shall be no greater than 1 in 270. This, in contrast with the Space Shuttle's actual LOC record of 1 in 67 (when it was designed for 1 in 100), brings into question how a commercial company can achieve such reliability and still ensure profitability. Another NASA requirement is for commercial

systems to provide an overall abort effectiveness of 95 percent, a requirement NASA itself has never met. The Constellation programs Ares I had an abort effectiveness of about 80 to 85 percent (NASA, 2010).

NASA has requested and implemented recommendations from the commercial space industry but the fear of excessive regulation is still a major concern. One of the lessons learned from the cancelled Constellation Moon Exploration Program was that “major aerospace contractors have sufficient processes such that NASA’s design and construction standards are of questionable value. This is a major driver of program fixed costs.” The recommendation from this lesson learned is that NASA “should assume the burden of meets or exceeds evaluations on itself instead of making the contractor prove it meets NASA requirements” and “most requirements should become guidelines or best practices.” The lessons learned also targets process simplification and makes a key point on NASA’s Constellation program requirements: “permanent or semipermanent waivers and deviations to requirements were the accepted norm” (NASA, 2011).

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V. COMMERCIAL SPACE TRANSPORTATION

The FAA defines space transportation as “the movement of, or means of moving objects, such as satellites and vehicles carrying cargo, scientific payloads, or passengers, to, from, or in space.” The U.S. commercial space transportation industry became prevalent after the loss of the Challenger Shuttle in 1986, which caused the banning of commercial payloads from flying aboard the Space Shuttle. Before the Challenger accident, all commercial satellites were launched by the government (FAA AST, 2010).

A. REGULATION

NASA has taken significant steps in ensuring the success of their partners in the COTS (Figure 5) and CRS programs. NASA’s continued investments in these programs are vital to enabling the commercial space transportation industry. In order for NASA to regain access to the ISS it will need to be flexible and willing to compromise with commercial space companies in some areas. A continued partnership between NASA, the FAA, and commercial space companies will be required for a successful space transportation market and to ensure redundant requirements do not stifle the emerging market. “NASA, FAA and the National Transportation Safety Board (NTSB for mishap investigations) should develop and implement clear and common requirements and regulations” (FAA, 2010).

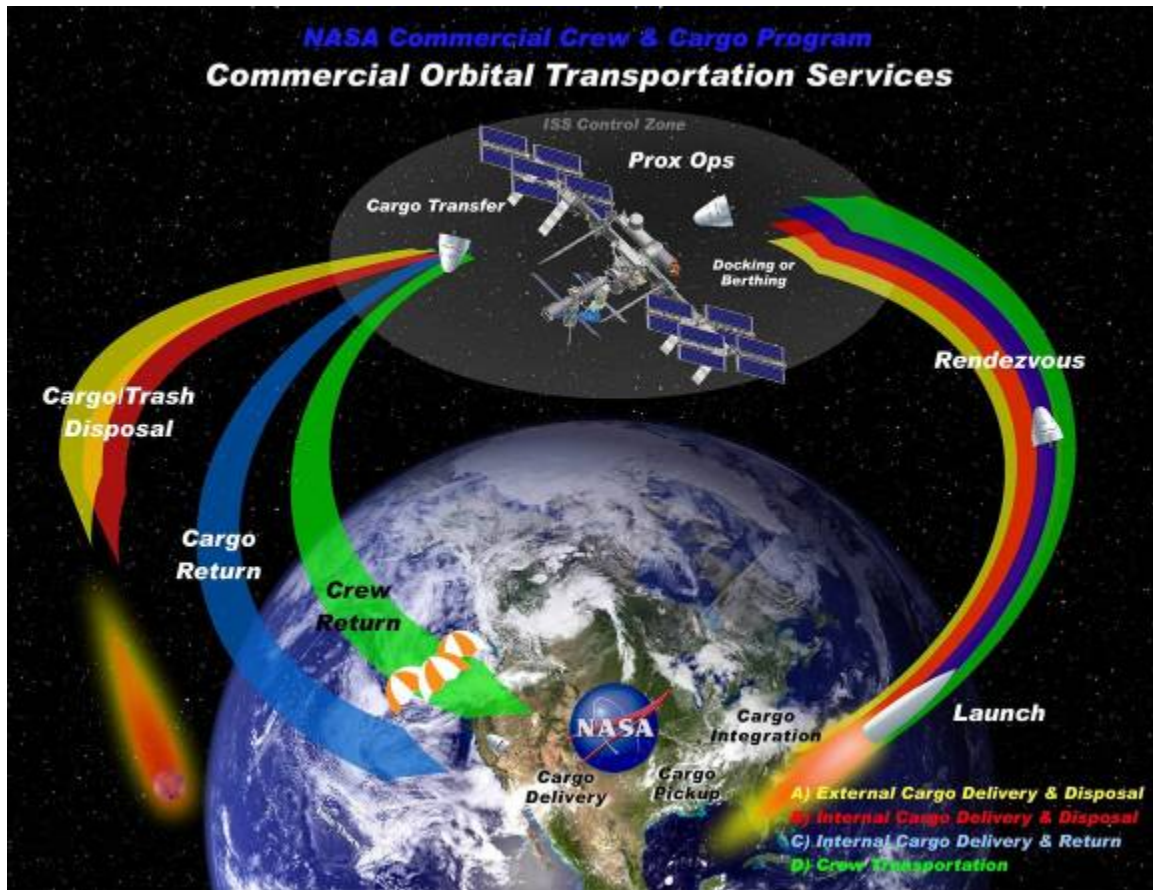


Figure 5. NASA COTS

NASA's missions will still require additional regulation to achieve their more strict survivability requirements. This additional regulation will come at a cost that NASA is partially funding through their CCDev program. While, this will result in increased safety for NASA's astronauts, it will become a burden to the commercial space industry for those without NASA funding or if NASA is unable to continue funding CCDev. If the emerging space market is profitable, NASA may have difficulty finding a commercial provider willing to meet their additional requirements if an easier and more profitable market exists. If this does happen NASA will have few alternatives other than to pay more for these services or to reduce their requirements. The only other alternative

would be to continue purchasing seats on the Russian Soyuz rocket to the ISS. The U.S. would not be in a good position to bargain for a reasonable price if no other alternative is available.

Government regulation of emerging markets is also a determining factor in an industries success or failure. Over regulation could lead to stifling the market while under regulation could lead to bad business practices or even a lack of basic safety requirements causing unnecessary risk. To prevent this, both NASA and the FAA requested input from private industry on their regulations and implemented their recommendations as part of their final products. This cooperation and co-ownership responsibility is important to ensure fair regulation and flexibility for the changing space transportation industry.

The regulatory standards governing human space flight must evolve as the industry matures so that regulations neither stifle technology development nor expose crew or space flight participants to avoidable risks as the public comes to expect greater safety for crew and space flight participants from the industry. (108th Congress, 2004)

One interesting aspect of both FAA and NASA regulations is the ability for a commercial company to demonstrate an alternate method of compliance for certain requirements. This means that if the company can prove their system can meet or exceed the FAA or NASA requirement, in a different but acceptable manner, then they can still receive approval without having to meet the specific requirement. This flexibility could allow the commercial industry to not only meet requirements more easily, but even demonstrate better ways of doing business.

B. SAFETY

The question of system reliability from a commercial company attempting to make a profit is also an important one. No existing rocket has a proven track record that meets NASA's required probability of LOC being less than 1 in 1000 launches. While such reliability is possible to achieve, it may come at a cost that is not feasible for most commercial companies. NASA's solution to this problem was to design a spacecraft with the ability to safely eject crew in case of a failure. The Constellation program and early

versions of the Space Shuttle were capable of ejecting their crew in an emergency. This is an example of how NASA achieves mission assurance through technology insertion. A commercial company is likely to instead focus on relatively simple systems with a greater emphasis on survivable aborts to ensure occupant safety without excessive costs (FAA, 2010).

The FAA will pursue safety through procedural improvements. The commercial industry will focus on operational safety but will also take into account cost effectiveness. As a research organization NASA implements their mission assurance and safety requirements through technology improvements. These three unique approaches to safety each have their own associated costs and benefits. Future safety regulation will have to account for all three disparate views and compromises will have to be made.

The FAA will initially focus on public safety as the commercial space industry matures. An accident during these early stages of development could have grave consequences. It is in the interest of all stakeholders to ensure safe operations; especially the commercial space industry. A major accident would receive extensive media coverage and jeopardize any business case and even a business's brand name. This may also force the FAA to step in and speed up regulation. While further regulation is expected and required, it may be more beneficial to the industry to allow it to develop its own lessons learned and best practices. At some point the FAA, just like the airline industry, will expand its regulations to include passenger safety as space transportation becomes more prevalent.

C. FORECAST

An emerging space transportation industry market forecast could be affected by many different factors including cost, schedule, performance, risk, technical, regulatory, and political. The risk of an accident resulting in the stand-down of operations for an investigation, and the uncertainty of informed consent being sufficient to protect commercial companies from lawsuits, presents a challenge to the industry.

1. Orbital Commercial Space Transportation

The emerging orbital commercial space transportation market has a small measure of certainty provided by the NASA ISS resupply and crew missions displayed in Figure 6 (FAA AST, 2011). Launch contracts have been signed and NASA's ISS traffic model for the ISS has been released. This consistent source of demand will be important in an otherwise uncertain market. The only historical demand for commercial orbital space transportation has been by a small number of space tourists who have paid to travel into orbit listed in Table 4 (NASA, 2011).

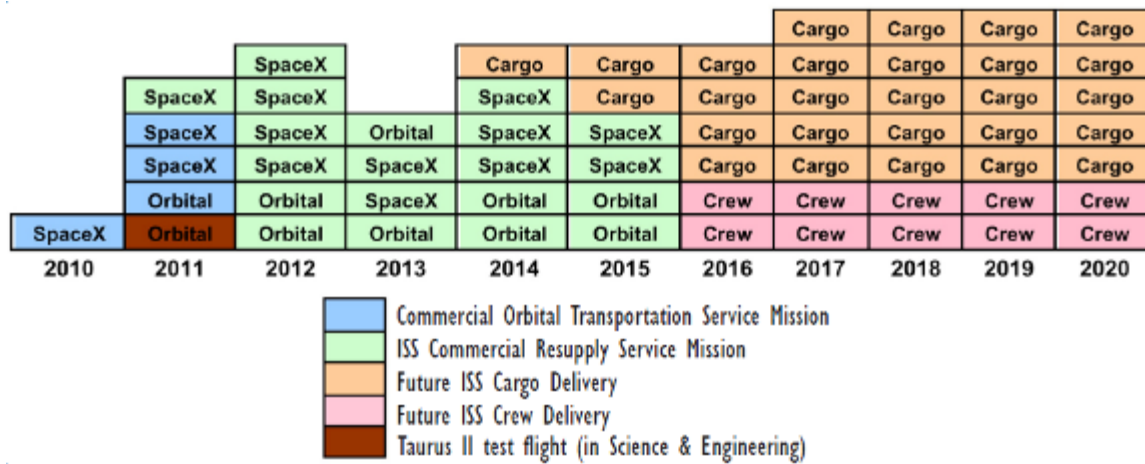


Figure 6. Forecast of COTS, CRS, and commercial crew flights to the ISS

Name	Reported Trip Price	Date Launched	Date Returned	Trip Duration
Dennis Tito	\$20M	4/28/2001	5/6/2001	9 days
Mark Shuttleworth	\$20M	04/25/2002	5/5/2002	11 days
Gregory Olsen	\$19M	11/1/2005	11/11/2005	11 days
Anousheh Ansari	\$20M	9/18/2006	9/29/2006	12 days
Charles Simonyi	\$25M	4/7/2007	4/21/2007	15 days
Richard Garriott	\$30M	11/12/2008	11/23/2008	12 days
Charles Simonyi	\$35M	3/26/2009	4/8/2009	14 days
Guy Laliberte	\$35M	9/30/2009	10/11/2009	12 days

Table 4. Space Tourists

After 2016 NASA plans on a more competitive market with more suppliers to meet their demands. Until then, NASA will serve as the anchor tenant customer to offset the lack of investment from an unstable market. NASA has developed SAA's with commercial companies for their crew and cargo transports to the ISS and this limits their control. NASA is still developing its acquisition strategy for the commercial industry. If NASA decides to switch from SAA's to the more traditional Federal Acquisition Regulations (FAR) it will add more control and oversight that will increase costs.

In 2011, the entire orbital launch market is forecasted to include 276 payloads requiring 130 launches. The majority of these launches are for commercial telecommunications. Iridium has recently signed the largest single commercial launch contract with SpaceX totaling 492 million U.S. dollars to launch its Iridium Next constellation. The historical orbital launch data for 2001 through 2010 is in Table 5. The FAA AST 2011 through 2020 forecast is included in Table 6 (FAA AST, 2011).

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Payloads											
Commercial Telecommunication	1	9	0	2	0	0	8	6	2	6	34
Commercial Remote Sensing	2	0	1	0	0	1	3	6	1	1	15
Science and Engineering	1	6	8	7	8	4	14	8	8	7	71
Commercial Cargo and Crew Transportation Services	0	0	0	0	0	0	0	0	0	1	1
Other Payloads Launched Commercially	0	0	0	0	0	0	0	0	0	0	0
Total Satellites	4	15	9	9	8	5	25	20	11	15	121
Launches											
Medium-to-Heavy Vehicles	2	2	1	1	0	2	10	4	2	7	31
Small Vehicles	2	2	3	1	3	3	2	6	3	1	26
Total Launches	4	4	4	2	3	5	12	10	5	8	57

Table 5. Historical Payloads and Launches

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	Avg.
Payloads												
Commercial Telecommunications	22	16	8	0	24	24	24	0	0	0	118	11.8
Commercial Remote Sensing	0	1	1	1	7	3	0	0	1	0	14	1.4
Science and Engineering	10	8	8	8	8	8	8	8	8	8	82	8.2
Commercial Cargo and Crew Transportation Services	4	6	4	6	6	6	7	7	7	7	60	6.0
Other Payloads Launched Commercially	1	0	1	0	0	0	0	0	0	0	2	0.2
Total Satellites	37	31	22	15	45	41	39	15	16	15	276	27.6
Launches												
Medium-to-Heavy Vehicles	11	11	9	9	15	15	13	9	10	9	111	11.1
Small Vehicles	0	2	3	2	2	2	2	2	2	2	19	1.9
Total Launches	11	13	12	11	17	17	15	11	12	11	130	13.0

Table 6. Payload and Launch Forecast

2. Sub-Orbital Commercial Space Flight

Predicting future demand in an emerging market that has only five previous launches (in 2004) is a difficult process full of uncertainty. With no significant historical data or published schedules there is very little data to base a forecast on. The earliest suborbital flight being advertised is for Virgin Galactic in 2012. They have already

received deposits from more than 400 flight participants willing to pay 200,000 dollars for a ride on SpaceShipTwo. Many other commercial companies have expressed plans for future launches including Masten, Armadillo, XCOR, and Blue Origin.

The demand for sub-orbital flights, beyond the scope of tourism, is uncertain. Many other markets that could benefit from these flights include: point-to-point passenger travel, time sensitive deliveries (such as human organs), microgravity research, and regional remote sensing. XCOR's Lynx aircraft has reserved at least six flights for microgravity research.

VI. MID-ATLANTIC REGIONAL SPACEPORT

A. HISTORY

The Mid-Atlantic Regional Spaceport (MARS) was established in 1997 by the Virginia Commercial Space Flight Authority (VCSFA), and is a state-funded, nonprofit organization. MARS leases land from NASA Wallops Flight Facility (WFF), which was established in 1945 and is under the direct management of NASA Goddard Space Flight Center. WFF is the oldest, most prolific launch site in the World in continuous operation with over 15,000 launches. A Reimbursable Space Act Agreement (RSAA) dictates how launch and range support will be provided to the VCSFA. This includes encouraging private sector commercial space use of NASA infrastructure and services in accordance with national space policy and Chapter 701 of Title 49, United States Code. These services would be provided on a noninterference basis as determined by NASA (NASA, 2007).

B. EXPERIENCE

VCSFA has made substantial progress with respect to regulation compliance, infrastructure development, launch experience, and planned operations to be well-positioned as a commercial launch site that has the potential for continued growth as a commercial spaceport. Table 7 lists past launches conducted at the MARS. Table 8 lists the current launch manifest for the MARS including the eight re-supply missions to the ISS.

Launch Date	Mission
December 2006	TacSat-2
April 2007	NFIRE
May 2009	TacSat-3
June 2011	ORS-1

Table 7. MARS Past Launches

Launch Date	Mission	Launch Pad
December 2011	Orbital Sciences Taurus II Rocket Test Flight	0-A
2012	Demonstration Launch of Orbital Sciences Taurus II Rocket	0-A
2012	Two Taurus II Re-Supply Missions to the ISS	0-A
May 2013	NASA LADEE	0-B
2013	Two Taurus II Re-Supply Missions to the ISS	0-A
2014	Two Taurus II Re-Supply Missions to the ISS	0-A
2015	Two Taurus II Re-Supply Missions to the ISS	0-A

Table 8. MARS Launch Manifest

C. MARS ADVANTAGES

MARS is co-located with a Federal range, the only NASA range, and has a payload mass advantage to higher-inclination orbits. This includes the best domestic launch azimuth to the ISS and minimal land overflight (See Figure 7). Minimal land overflight is an important cost advantage when insuring launches. WFF maintains an aeronautical research airport, with two 8,000-foot FAA-certified runways, that can support large transport aircraft. The FAA managed airspace surrounding WFF includes the airport control zone, restricted and warning areas. NASA also maintains a fully

equipped, state-of-the-art Range Control Center, fixed and mobile telemetry, optical, and television systems, an extensive fixed and mobile-instrumented range, and many other support services (NASA WFF, 2010).



Figure 7. MARS Launch Profiles

WFF is the only orbital launch facility owned and managed exclusively by NASA. This NASA ownership and management allows easier scheduling and a higher degree of certainty for scheduling launches. WFF has facilities for the receipt, inspection, assembly, checkout, and storage of rocket motors and other pyrotechnic devices. The launch site includes six launch pads, three blockhouses, assembly buildings, and radar facilities for tracking and surveillance (Maryland, 2011).

The Commonwealth of Virginia has implemented many incentives to lower the tax burden of commercial space companies to reduce the costs and risks of doing business in Virginia. These incentives were implemented to promote job growth and

development of the commercial space industry. Businesses sponsored by the VCSFA for ISS resupply are exempted from Virginia sales and use taxes due to the Zero G Zero Tax Act of 2008. This was preceded by the Liability and Immunity Act of 2007, which reduced commercial space companies' risk in pursuing human space flight. MARS and WFF are also located within a Foreign Trade Zone. This makes hardware and equipment exempt from import/export duties (FAA CST, 2009).

Other advantages to federal government, domestic commercial and international launch customers (Joint Maryland and Virginia Working Group, 2004):

- Unique orbital access afforded by a mid-latitude launch site;
- Available capacity to responsively meet launch needs and absorb new business;
- A Federal license to conduct commercial space launches;
- A formal partnership with NASA that permits and enables use of the Wallops Flight Facility and its personnel;
- User-friendly local, state, regional and federal synergistic infrastructure;
- Range safety afforded by immediate coastal proximity to the over-water Atlantic range airspace complex;
- Access to mid-Atlantic and national-capital area, federal and commercial technology organizations;
- Available host facilities and industrial parks to host business growth;
- Available local workforce;
- Business friendly state government institutions willing to support development and expansion of technology firms;
- A tradition of creativity and an open exchange of knowledge consistent with security needs;

D. REGULATION

As a commercial spaceport, MARS falls under FAA regulation and is licensed as a site operator for commercial launches. However, due to its collocation with a Federal range it must also meet NASA regulations. Some of the FAA requirements may be fulfilled by the Federal range's assessments. For example, the flight safety analysis may

be met through the FAA process or by using an existing Federal range's analysis. Federal launches by the DoD or NASA do not currently require an FAA license if they contract directly with the Federal range.

Every FAA licensed launch will include a policy, safety, payload, and environmental review and must meet launch insurance requirements. In addition, a launch operator on a Federal range must also be compliant with the Federal range's safety guidelines (14 C.F.R. §415 subpart C). The NASA and FAA range requirements are expected to be more compatible in the future to reduce duplicate regulation. This combination of disparate entities will be a difficult process that will take extensive effort from both agencies. It is vital that "NASA and the FAA agree on a coherent set of requirements and regulations that enable fielded systems to serve both government and non-government customers" (FAA, 2010).

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VII. RECOMMENDATION AND CONCLUSION

The MARS needs to continue to distinguish itself as a leading spaceport. Virginia has led the way in promoting its space industry and will need to continue these efforts. The symbiotic relationship between the MARS and NASA's WFF will need to continue to evolve. With the declining NASA budget a thriving commercial space industry will be vital in reducing operating costs and ensuring stability and growth during a time of Federal downsizing. NASA has studied the possibility of closing WFF several times. This closure has been prevented by strong political opposition. It is in the best interests of the MARS, NASA, and the commercial space industry to ensure each other's success and continued utilization of WFF.

Since NASA awarded Virginia-based Orbital Science Corporation a CRS contract, a consistent line of funding is in place that must be utilized to the greatest extent possible. NASA will be required to purchase, at a minimum, another 27 cargo flights and 10 crew flights through 2020. The existing contract and the possible future NASA contracts should be used as the anchor tenant to attract more business. The U.S. Air Force Operationally Responsive Space Office has launched four spacecraft from Wallops with the possibility for more launches in the future. This relationship should continue to be developed and MARS promoted as a responsive, lean launch provider. While the orbital market has a much higher entry cost than the sub-orbital market, continued demonstration of MARS as a lean launch provider could attract emerging space companies like Bigelow Aerospace.

The sub-orbital market should take advantage of WFF's existing airport and infrastructure to perform sub-orbital flights. The MARS' unique location on the East Coast and near the nation's capital, and other population centers, places it in a key position to offer sub-orbital flights. The sub-orbital tourism, point-to-point, and research markets are likely to be the highest in demand and should be targeted for future growth. Wallops has a long history of suborbital research and could expand this field to include more commercial launches.

FAA's commercial space transportation regulations are in their infancy but are still minimal. The NASA regulations while more mature and far more complex are being adapted for commercial usage. NASA plans on leaving all commercial space licensing to the FAA. In the future even a NASA mission launched from a Federal range would require an FAA license. NASA is likely to still have their own safety requirements that will be redundant to FAA requirements. A key part to enabling commercial space transportation industry at MARS is reducing the uncertainty about how NASA and FAA regulations will coexist.

The nascent commercial space transportation industry has been enabled by NASA investment in COTS, CCDev and CRS. This, along with the FAA's matching grants and other Federal and state incentives, has helped jump-start the commercial space transportation industry. The possible roadblocks of excessive regulation have been minimized by the FAA's limited Final Rule on Crew and Space Flight Requirements and the CSLAA. By not certifying vehicles as safe, the FAA acknowledges that passengers will fly at their own risk. While this congressional "hands off" mandate will encourage research and development in this emerging market it could backfire if an accident occurs that results in more strict regulation.

After December 23, 2012 the FAA may propose new regulations on the commercial space industry without restriction. The amount of regulations will be dependent upon how much the commercial space industry has matured. Industry lessons learned and best practices are needed to determine future requirements. The FAA has already held public meetings to address many of the concerns facing this emerging market. Specifically, the deconfliction of FAA and NASA regulations will be necessary to prevent duplication of efforts. Both regulators need to ensure their requirements are compatible or complementary for both government and non-government organizations.

The development of a robust commercial space transportation industry is important to the U. S. and its National Security in many different areas. Economically, a strong space industry and a vigorous space launch schedule will promote space jobs and programs to stay in the U. S. A larger and more experienced space industrial base will

greatly benefit National Security Space programs and develop national capabilities in new technical realms. Another important impact to National Security Space is the required expansion and growth of the space transportation infrastructure. Similar to the railroads, interstate highways, and airports of today a space transportation infrastructure will need to be developed and will be a requirement for future growth and expansion. Without this infrastructure National Security Space will be required to maintain its own aging infrastructure and would not be able to benefit from new construction, technology and innovations that the commercial space sector would develop on its own.

In a shrinking Global economy the commercial space industry will be vital in maintaining the competitive edge in, and our access to, space. The more developed the U. S. commercial space industry is the more likely it will be able to adapt and overcome any challenges it is faced with. It is in the U.S. Government's strategic interest to remain a leader in the Global space transportation industry. This emerging commercial space transportation market has the potential to become a thriving industry with proper investment and minimal regulation.

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